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13. ABSTRACT ***(Maximum 200 Words)*** The Navy must design and engineer ships and systems for the Sailor at the onset of the design and acquisition cycle. A seamless and comprehensive fusion of people, hardware, and software is—or must be—a principal goal of all engineers and designers, program managers and acquisition specialists, logisticians, and operators. If we seek to maximize operational effectiveness and ensure mission success as our ships go in harm's way, while at the same time we strive to minimize total ownership costs, we must design and engineer the *total system* for *maximum warrior performance.* Most fundamentally, that means ensuring that the human is taken into account, up front, in system and platform design and engineering. This paper addresses the charter, roles, tasks, and progress of NAVSEA 03 during the past year, as it proceeds to ensure the total integration of the Sailor into the systems and ships the Navy is designing, engineering, and acquiring.

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The Role of the Sailor as a Networked Element of Sea Power 21: Engineering Ships for the Sailor

Introduction

In his "Sea Power 21" strategic concept paper released last fall, Chief of Naval Operations Vern Clark recognized the human, the Sea Warrior, as "a premier element of all operational systems." Admiral Clark's Sea Warrior initiative has underscored the Navy's commitment to the growth and development of its people. "As optimal manning policies and new platforms such as the DD (X) and Littoral Combat Ship reduce crew size further, the Navy will increasingly need Sailors who are highly educated and expertly trained," Admiral Clark has noted. "All the advanced technologies will be for nothing," Admiral Clark recognized, "unless we have the right people, with the right skills, where and when we need them."

Just as important, however, is the realization that the Navy must design and engineer ships and systems for the Sailor at the onset of the design and acquisition cycle. Indeed, a seamless and comprehensive fusion of people, hardware, and software is—or must be—a principal goal of all engineers and designers, program managers and acquisition specialists, logisticians, and operators. In short, if we seek to maximize operational effectiveness and ensure mission success as our ships go in harm's way, while at the same time we strive to minimize total ownership costs, we must design and engineer the *total system* for *maximum warrior performance*. Most fundamentally, that means ensuring that the human is taken into account, up front, in system and platform design and engineering.

In fall 2002, Vice Admiral Phillip Balisle, Commander, Naval Sea Systems Command (NAVSEA), announced the creation of a new Human Systems Integration (HSI) Directorate (NAVSEA 03). The HSI Directorate serves as NAVSEA's single point of contact for all HSI- and human performance-related long-range strategic planning, policy, acquisition issues, future research and development investment, and technology insertion into existing and future surface ship and submarine systems.

This paper addresses the charter, roles, tasks, and progress of NAVSEA 03 during the past year, as it proceeds to ensure the total integration of the Sailor into the systems and ships the Navy is designing, engineering, and acquiring. This integration will guarantee the most beneficial Sailor work environment as well the most effective total system performance at the lowest total ownership cost. The effective application of human systems engineering, optimal manning, tailored training, and measured human performance are key to this success. This objective is to be reached by ensuring that the Sailor is given equal emphasis with technology, equipment, computers, and software applications during ship development. NAVSEA 03 is pivotal in this quest.

Why HSI?

Current and future Navy ships and systems make severe demands on the readiness, performance effectiveness, and mental and physical capabilities of the Sailors who operate them. In order for these systems to operate accurately and effectively, it is necessary to consider Sailor

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capabilities and efficiencies very early in the design and acquisition processes. Human Systems Integration is required to consolidate the various disciplines of systems engineering and acquisition that address the roles, requirements, provisions, and accommodations for humans in complex systems.

HSI is a specialized, formal engineering discipline, essentially the marriage of systems engineering and behavioral science. The fundamental objective of HSI is to influence system design and engineering such that human capabilities and limitations are taken into account to ensure the resulting systems will have the highest and safest performance at the lowest total ownership cost (TOC).

Total system performance enables superior warfighting capability. It includes the performance of all three critical components - hardware, software and the Sailor. In fact, Sailor performance is THE critical element of total system performance. "Without highly motivated and well-trained Sailors and Marines, our ships, airplanes and submarines are lifeless and inanimate platforms."[1] Sailor performance is exclusively derived through the application of HSI principles.

There are ten crucial elements of human systems integration:

- Top-level leadership ensuring HSI becomes part of the organization culture
- Focus on human-centered design
- Source selection policy
- Organizational integration of all HSI domains
- Documentation integration into procurement process
- Quantification of human parameters
- HSI technology
- Test and evaluation/assessments
- Highly qualified practitioners
- Education and training program[2]

HSI affects many functional areas related to ship systems acquisition including: manpower, personnel, and training (MPT); human factors engineering (HFE); habitability; personnel survivability; and safety and occupational health (SOH). By incorporating HSI principles early in the acquisition process, NAVSEA can ensure that the ships and systems it procures are designed for optimal performance.

Fundamentally, when the focus is maintained on the human elements, both operators and maintainers, during the design and acquisition of any Navy system, it will result in a dramatic reduction in total ownership cost and a dramatic improvement in total system performance and productivity.

The requirement for human factors to be considered during the design and acquisition of Navy Systems is not new by any means. In fact, in 1985 the Naval Sea Systems Command issued an instruction (3900.8) requiring ship and system acquisition managers to "identify human factors requirements in their acquisition plans and ensure that sufficient resources are available to satisfy these requirements."

The Department of Defense's most current instruction, DODI 5000.2 (2003), states that the program manager "shall have a comprehensive plan for HSI in place early in the acquisition process to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system."

As Admiral Clark referenced in Sea Power 21, the Navy has reached an era where, in order to fund new, transformational Navy systems, it is necessary to optimize manning complements to reduce a significant part of total ownership cost. In this context, optimized manning should be understood as the minimum crew size consistent with risk, affordability, human performance

[1] COMNAVSEA memorandum Ser 10/236 dated 11 Sept 02

[2] See *Handbook of Human Systems Integration*, edited by Andrew P. Sage, 2003, p. 13.

capability, and human workload.[3] If the manning complement is determined early in acquisition development and appropriate human systems integration can be used to optimize its size, then it follows that human systems integration principles and tools must be applied very early in the acquisition process.

Program Managers for all platform and systems acquisition and modernization programs can reap the benefits of superior warfighting capability, optimal manning and lowest TOC by performing HSI tasks and activities. Most importantly, the Sailor benefits – not only the immediate system user but also the generations of Sailors that will be using the same system thirty to fifty years after him or her.

Critical HSI tasks and activities that Program Managers and their staffs should be performing include:

- Develop, resource, and sustain an HSI plan providing a comprehensive process for addressing HSI issues and concerns throughout the system acquisition and/or modernization process.

- Conduct a Top-Down Requirements Analysis (TDRA) to determine manpower and human performance requirements in terms of sailor functions, tasks and required knowledge, skills and abilities. This critical analysis is required for all personnel who will interface with this system, including system users, operators, maintenance personnel and support personnel. System engineers and designers conduct this analysis for appropriate missions with traceability to HFE and human-centered design analyses.

- Furthermore, determine human performance requirements of the system based on the system description, anticipated skills, and projected characteristics of target occupational specialties and recruitment and retention trends. Identify high driver skills and occupational specialties and minimize potential issues.

- Design, develop, prototype and test the system being acquired or modernized to meet the afore-mentioned human performance requirements.

- Apply current HFE standards and integrate HFE with systems engineering to provide for effective human-machine interfaces and mitigate safety and health issues. Current HFE standards include American Society for Testing and Materials (ASTM) F1166, Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities; or MIL-STD-1472F, Human Engineering.

- Address detection of and protection against instantaneous, cumulative and residual nuclear, biological and chemical weapon effects.

- Evaluate Environment, Safety and Occupational Health (ESOH) hazards and risk mitigation strategies.

- Establish requirements for living and working conditions, the physical environment and personnel facilities to optimize mission readiness, crew morale, professional development and retention.

- Implement Program Performance metrics to track the success of incorporating HSI in acquisition and modernization programs; and

- Define appropriate human performance metrics and determine where to incorporate these metrics to measure and track improvement of Sailor performance.

To achieve optimal manning, the HSI process presents the events, activities, decisions, and guidelines involved in applying HSI methods, tools and data at each phase of the system

[3] See "Optimized Crewing for Surface Ships," by Patricia S. Hamburger, J. Robert Bost, and Jennifer A McKneely, *Naval Surface Warfare Center, Dahlgren Division Technical Digest*, 1999.

acquisition process. The endeavor begins with a Top-Down Requirements Analysis, which defines human requirements early in system development. The TDRA is concerned with identifying and analyzing requirements for missions, system functions, and human involvement in the performance of functions. These requirements lead ultimately to the development of design and employment requirements for HSI-compliant systems and procedures.

Reducing total ownership cost is not the only reason to implement HSI principles early in system acquisition. Proper consideration of the human element in the total system also reduces the incidence and impact of human errors, which are the direct cause of 80% of ship accidents, according to a recent British maritime insurance study. The other 20% can be attributed to mechanical or technological failures or meteorological factors.

HSI also enhances situational awareness and decision-making when it is applied to how information is displayed to the warfighter. Also, with fewer persons on board, attention can be given to improving ship space habitability, provisions, and amenities such as increased privacy and recreational arrangements. In addition, quality of work at sea is addressed by emphasizing ergonomics and automating some of the more monotonous or dangerous shipboard tasks. Finally, the application of HSI enhances Sailor performance capabilities, providing more tailored, advanced training.

Who is NAVSEA 03?

In a memorandum promulgated September 11, 2002, NAVSEA Commander Vice Admiral Phillip Balisle announced the formation of the Human Systems Integration Directorate (NAVSEA 03); the Directorate was officially created on 1 October. In his announcement, VADM Balisle stated that "Sailors clearly are the 'Navy's most valuable shipboard system', and our duty is to ensure that every ship we build and system we deliver is designed, acquired and supported with their performance, training, safety and survivability in mind."

In subsequent memoranda, VADM Balisle established technical and certification authority in NAVSEA 03 and appointed Mr. J. Robert Bost as the warranted HSI Technical Authority. As NAVSEA HSI technical and certification authority, NAVSEA 03 coordinates HSI responsibilities with appropriate organizations internal as well as external to the Department of Defense, and assists the Fleet and the Chief of Naval Operations with developing HSI requirements. The Directorate is accountable to Commander, NAVSEA, for certifying that the systems delivered to the Fleet are "usable, enhance Sailor performance, optimize manpower and training, and promote safety, survivability, and quality of service.

The HSI Directorate has also been chartered to:

- Establish corporate NAVSEA HSI policy and standards, develop human performance metrics and evaluation techniques, and conduct periodic reviews of acquisition program HSI plans and products.

- Work closely with Commander, Fleet Forces Command (CFFC), the Chief of Naval Operations, Naval Education and Training Command (NETC), and Navy Personnel Development Command (NPDC) to support and implement Task Force Excel initiatives, to establish a Total Ship Training System Roadmap, and to provide technical assistance to Program Executive Officers (PEOs) and Program Managers to ensure alignment with appropriate Learning Centers, waterfront technical support activities, and Fleet training organizations.

- Educate the NAVSEA workforce and ensure HSI policy, procedures, and best practices are implemented and integrated into the total systems engineering process.

- Provide direct assistance to program offices and coordinate external assets to develop and sustain system HSI plans.

Since its inception in October 2002, NAVSEA 03 has accomplished the following:

1. Institutionalized HSI as a "best business practice" throughout NAVSEA and its affiliated Program Executive Offices (PEOs). Furthermore, NAVSEA is leading the drive to institutionalize HSI across all of the SYSCOMs (via the Virtual SYSCOM), in the Fleet (via the Fleet Readiness Plan process) and in the manpower, personnel and training communities (via Sea Warrior)

2. Promulgated program and human performance metrics resulting in a measurable framework for certifying that ships and systems delivered to the Fleet are optimized for sailor performance.

3. Integrated HSI into corporate NAVSEA policy and guidance. These policies permit SEA 03 to guide and assess the development of all our systems as they work through their milestones to Fleet operations.

4. Assessed 15% of the programs of record, including the DD (X), LPD-17, Littoral Combat Ship, and CVN-21 programs. These "program reviews" resulted in improved HSI technical designs, alignment of program HSI activities and greater program focus on HSI in general. NAVSEA 03 is leveraging these program assessments to determine how to *programmatically* certify acquisition and modernization programs for HSI. To date, NAVSEA 03 has assessed *program performance* in all seven HSI technical domains, in HSI management and HSI funding. As stated above, NAVSEA 03 has developed program performance metrics to assist Program Managers with incorporating and measuring how well they are implementing and executing HSI in all aspects of their programs. These metrics are program-specific based upon the complexity of the system, type of acquisition, ACAT level and maturity of the program in the acquisition process.

5. Created a measurable HSI certification concept, with the first certification planned for DD (X) and LCS Preliminary Design Reviews. Promulgating milestone-driven certification criteria ensures that these program managers are executing HSI tasks and activities that will result in the delivery of the Navy's future fleet that enhances sailor performance with optimal manning.

6. Incorporated HSI into the SHIPMAIN Alteration and Modernization approval process that will result in ensuring that each Alt and Mod is designed to optimize Sailor performance using the right number and skill mix of operators and maintenance personnel. Furthermore, the process will ensure that training is designed and planned prior to programming the Alt's installation. SEA 03 will leverage this achievement to build its certification authority in this area.

7. Incorporated HSI Risk Criteria and metrics into the Commander, Fleet Forces Command (CFFC) C5I Modernization and Baseline approval process. Recently, SEA 03 "piloted" the use of these metrics in support of USS CARL VINSON Availability. As above, SEA 03 will leverage process and business rules "lessons learned" to build its certification authority in this area.

8. Conducted baseline human performance testing aboard USS CHAFEE (DDG 90). For the first time ever, this total system performance test captured quantifiable and observable workload and situational awareness drivers and timeliness of CIC operator actions that will lead to improved warfighter performance. By measuring *human performance* as a critical component of total system performance, SEA 03 was able to directly measure how HSI benefits Sailor performance. SEA 03 will leverage the valuable "lessons learned" from this test to complete its certification authority.

9. Chartered the Human Performance Lab (HPL) at Naval Surface Warfare Center, Dahlgren, to conduct integrated total system performance testing in future systems. Furthermore, SEA 03 is integrating the HPL with the Integrated Command Environment, Distributed Engineering Plant and Command & Control, Open Architecture and Composeable FORCENet Labs to create a world-class total system performance-testing infrastructure. SEA 03 plans to leverage this infrastructure to conduct integrated total system testing in support of deploying Strike Groups as early as this summer.

10. Integrated the Interoperability testing and training processes and guidelines with the FRP.

11. Conducted a pilot program on the REAGAN Strike Group that resulted in a $2M savings in Strike Group training costs. The pilot included institutionalizing an Integrated Training Officer (ITO) as part of the REAGAN Strike Group team. The ITO developed a coordinated testing and training strategy overlapping wherever possible training with test events. By using shared resources (ships, aircraft and labs) the Center for Surface Combat Systems (CSCS) did not have to fund these assets independently resulting in the savings in training costs as compared with previous Strike groups.

12. Working with SPAWAR, NAVSEA 03 initiated an Integrated Battle Force Training (IBFT) tool pilot program that addressed training for select Combat and HM&E systems onboard LINCOLN and HARRY S. TRUMAN Strike Groups. This initiative identified training shortfalls prior to FRP surge operations and provides web-enabled hull-specific tailored training plans. SEA 03 will leverage this initiative to improve Strike Group Training Readiness for all systems using the Battle Force tool. In so doing, SEA 03 and Program Managers will align training and skills between the acquisition community and Sea Warrior.

13. Published and distributed the *Navy Ship Systems Program Manager HSI Guide* to assist in development of future ships and systems.

14. Led the Navy's drive to establish Sea Warrior as the premier Human Capital Management System in the world. SEA 03 served as a core member of the Task Force Warrior team by providing program management support, infusing acquisition discipline and providing HSI input to acquisition criteria for the Sea Warrior Implementation Roadmap.

15. Achieved alignment between the Naval Personnel Development Command, Naval Education and Training Center, affiliated Navy learning centers, warfare centers and the Fleet. The result of this effort has resulted in improved link training, faster turnaround time for learning centers to get technical data and is establishing business rules for the Integrated Learning Environment technical data repository. SEA 03 is leading the latter effort that will result in integrated and reusable technical data and training objects.

16. Authored, signed and published the Virtual Systems Command HSI memorandum of agreement. NAVSEA is leading the Virtual SYSCOM to establish common HSI technical and certification authority policies, promulgate common HSI metrics, identify and institutionalize HSI 'best practices' that are compatible with Sea Warrior and assist with developing guidelines for a standard presentation layer for all LCS modules.

17. Engaged with numerous efforts to incorporate HSI into requirements documentation. These included DOD 5000, LCS Flight 0 Request for Proposal, CVN-21 Operational Requirements Document and the Navy's FORCENet report to Congress.

18. Conducted an aggressive campaign to educate the NAVSEA and program executive office workforce

These initial steps provide the foundation for establishing human systems integration as a fundamental best business practice for Navy acquisition.

NAVSEA 03 has also reached out to other Navy communities via symposia and conferences to educate the Navy writ large about the implementation of Human Systems Integration.

HSI in future ship programs

The application of HSI and the influence of NAVSEA 03 are most visible in new ship acquisition programs, most notably CVN-21, DD (X), and the Littoral Combat Ship (LCS). In these programs, HSI is crucial to accomplish the ships' missions with drastically reduced manning. By applying the aforementioned HSI principles early in the design, acquisition and modernization processes, NAVSEA 03 is assisting key acquisition programs such as LCS, DD (X) and CVN-21 to be certified for HSI.

CVN 21

The Navy's next-generation aircraft carrier, CVN 21 will be crewed by as many as 900 fewer Sailors than previous carriers. This Key Performance Parameter has greatly affected the way major shipboard systems are being designed and employed. NAVSEA 03 is assisting the CVN 21 program office to achieve this challenging goal by performing thorough technical reviews of the requirements documents to ensure that proper HSI standards are observed throughout.

NAVSEA 03 is assisting CVN 21 program officials with the following:

- Develop the CVN 21 HSI Plan and participate in all HSI Working Groups and Integrated Product Teams (IPTs) to address HSI within the ship design process.
- Require industry to meet ASTM F1166 HFE standards and integrate HFE with systems engineering (including function and task allocation) to provide for effective human-machine interface.
- Perform a Top-Down Requirements Analysis to identify required functions, tasks and skills to aid in reducing manpower
- Aid in the development of human performance metrics.
- Integrate HSI requirements in requirements documentation such as the CVN 21 Operational Requirements Document (ORD).
- Develop a Programmatic ESOH Evaluation (PESHE) and National Environmental Policy Act (NEOA) Strategy.

DD (X)

In June 2003, the General Accounting Office released a report to Congress in which it praised the DD (X) destroyer program for placing significant emphasis on human systems integration early in the acquisition process and establishing an aggressively low target crew size, currently 114. This goal was established at the inception of the program and provided the initiative for developing a comprehensive human systems integration plan.

NAVSEA 03 has been working with the DD (X) program office to establish first-ever Sailor System Specifications (SSS) which will result in every crew member possessing the right knowledge, skills and abilities enabling them to operate, monitor and maintain DD (X) hardware and software. The SSS also includes the capabilities required to train, sustain and support personnel throughout the system life cycle. These specifications will become the measurement criteria for Human Performance.

Specific initiatives that the DD (X) program have undertaken to implement HSI include the

development of the Total Ship Computing Environment (TSCE), based on open architecture, to integrate all shipboard computing systems and interfaces with required off-ship systems to support concurrent shipboard operations. DD (X) integrated control systems interface with the TSCE for a total system approach to controlling shipboard equipment that supports manpower reduction objectives. The program has also collaborated with Naval Surface Warfare Center, Dahlgren Division, on the Integrated Command Environment, which will revolutionize the "traditional" Combat Information Center.

Littoral Combat Ship (LCS)

Much like DD (X), the LCS will have rigorous combat requirements with a constrained core crew size, perhaps between 15 and 50. The LCS Interim Requirements Document (IRD) states that the ship will use human-centered design to automate decision processes and optimize manning

The LCS program faces perhaps the greatest yet human systems integration challenges because of the number of crew that will be challenged with operating the ship in a warfighting theater. NAVSEA 03 is working closely with LCS program officials to ensure that human systems integration principles are applied to the design of the ship and its systems, for the benefit of Sailors and the total warfighting performance of the ship. Some of the key accomplishments and ongoing initiatives that SEA 03 and LCS program officials are working on include:

- Continue to incorporate HSI in all critical acquisition documentation including: Final Design/Detail Design & Construction Request for Proposals, the Initial Capabilities Document (ICD), the Capabilities Development Document (CDD), Mission Package Top Level Specification and the Test and Evaluation Master Plan (TEMP).

- Provide greater visibility to HSI funding in the LCS contract.

- Ensure HSI reps are engaging with all LCS Integrated Product Teams (IPTs)

- Integrate the Seaframe with Mission modules in the TDRA to identify total ship requirements. When completed, the HSI Plan will address both the Seaframe and Mission Modules.

- Numerous initiatives to reduce Flight 0 Mission module workload through automation and function consolidation.

- Address shore support manpower requirements.

- Develop KSAs for the total ship targeting the use of Sea Warrior classification concepts.

- Develop a Training Roadmap and design an LCS Total Ship Training Architecture (TSTA) that maximizes the use of new learning techniques, simulation technology and embedded training.

Conclusion

The formation of the Human Systems Integration Directorate within the NAVSEA corporate structure emphasizes the importance the Navy's acquisition community has put on engineering ships and systems from day one with the Sailor's performance in mind.

By inserting waypoints that ensure HSI inclusion into the design and acquisition process, NAVSEA proves that the command is recognizing and incorporating the critical impact of the human on total system performance. Future ships will be designed and will operate much differently due to the application of the principles of human systems integration, which will greatly alter the appearance and deployment of tomorrow's Navy.